Looking Ahead: An Introduction to Five Exploratory Studies of Fast ForWord

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In this paper, we provide an introductory overview of a novel approach to language intervention called Fast ForWord (FFW), developed by the Scientific Learning Corporation. More than 20,000 children have received FFW intervention, and many researchers, clinicians, educators, and parents are asking questions about the effectiveness of FFW. To date, there are few evaluations of the treatment other than those that have been published by the developers of the FFW program. This introductory paper will discuss the underlying hypotheses associated with FFW, the components of FFW, and the few studies that have been published regarding the efficacy of FFW. A clinical outcome model based on the work of R. R. Robey and M. C. Schultz (1998) is proposed as a way of understanding the contributions and limitations of previous intervention studies on FFW and as well as those presented in this issue. We end with a look at the questions that need to be asked by researchers and clinicians who are interested in FFW.

Key Words: auditory processing, clinical outcomes research, language impairment in children

Approximately 7% of all school-age children in the United States have unusual difficulty learning and using language despite adequate hearing, nonverbal intelligence, and motor abilities (Leonard, 1998; Tomblin, Records, & Zhang, 1996). This difficulty, which is known by a variety of terms including language-learning disability, specific language impairment (SLI), and language-learning impairment (LLI), has serious social, academic, and vocational implications (Aram & Hall, 1989; Snowling & Hulme, 1989; Stothard, Snowling, Bishop, Chipchase & Kaplan, 1998; Tallal et al., 1997).

Children with language impairments frequently are enrolled in language intervention during early childhood; many continue receiving some form of treatment throughout their school years (Aram & Nation, 1980; Bishop & Adams, 1990; Bishop & Edmundson, 1987; Stothard et al., 1998). A wide range of treatment approaches is used, and the results of most language intervention studies suggest that intervention is effective (see Leonard, 1998, for a review). With more than 1 million children receiving language treatment in public schools across the United States each year, it is surprising that the literature on intervention with school-age children is meager (U.S. Department of Education, 1997). This means that, despite decades of providing language intervention to children in public school settings, there are few studies measuring outcomes related to the intervention.

Recently, Merzenich, Jenkins, et al. (1996) and Tallal et al. (1996) provided evidence that intensive intervention involving modified speech stimuli can be effective for school-age children with LLI. Merzenich, Tallal, and their colleagues at Scientific Learning Corporation (SLC) used these pilot studies as the basis for a novel approach to language intervention called Fast ForWord (FFW; SLC, 1998). The developers of FFW assert that their computer-based intervention leads to neural reorganization that causes an increased ability to perceive rapidly changing acoustic input (Merzenich, Jenkins, et al., 1996; Merzenich, Saunders, et al., 1999; Tallal et al., 1996; Wright et al., 1997). Their claims about this new language intervention program have received a great deal of attention in the lay press and generated lively discussion in the scientific literature (see Veale, 1999, and Gillam, 1999) and at professional meetings.

Thousands of children have received FFW intervention in clinics or in public and private schools, and many researchers, clinicians, educators, and parents are asking questions about the effectiveness of FFW (SLC Web Site, 2001). To date, there are few evaluations of this treatment other than those published by the developers of the FFW program. The primary aim of this clinical forum on FFW is to provide much needed data on the outcomes of the program from independent laboratories. We hope that this forum can assist parents, educators, and clinicians when making informed treatment decisions. This introductory paper will discuss the underlying hypotheses associated with FFW, the components of FFW, and the few studies that have been published regarding the efficacy of FFW. We end with a look at the questions that need to be asked by researchers and clinicians who are interested in FFW.

Historical Review of the Theory of Auditory Temporal Processing and Language Impairments in Children

Some of the first work linking temporal processing with language disorders appeared in the mid-1960s with Efron's (1963) observation that temporal sequence discrimination is disturbed in adults with aphasia who have temporal lobe disease in the dominant hemisphere. Efron interpreted this finding as suggesting that there is a "fundamental mechanism or process related to the requirements of 'time-labeling' of input and output signals which is located in the dominant temporal lobe" (p. 419). Shortly thereafter, others posited the presence of auditory temporal processing deficits in children identified with language impairments (LI) (Hardy, 1965; Lowe & Campbell, 1965). Lowe and Campbell were the first to compare the performance of children with LI to that of children with normal language (NL) on two different tasks using nonlinguistic stimuli. In the first task, the participants were to detect two identical pure tones presented in rapid succession; in the second task, they were to sequence two pure tones of different frequencies presented at varying interstimulus intervals (ISIs). In the first task, the LI participants required ISIs nearly twice as long as those required by the NL participants to perceive the two tones. Similarly, in the second task, the LI participants were successful in correctly sequencing the stimuli when the ISI exceeded 250 ms, whereas the NL participants were successful at ISIs of 40 ms.

In a series of studies, Tallal and colleagues demonstrated that children with LI were less able than control children to process short, rapidly sequenced auditory information (Tallal & Piercy, 1973, 1974, 1975). These experiments included nonverbal stimuli (Tallal & Piercy, 1973) as well as sequences of stop consonants and vowels (Tallal & Piercy, 1974, 1975). A fundamental assumption of these early studies was that children with LI have difficulty discriminating and sequencing stimuli that consist of short tones, short vowels, or short transition consonants when they are presented with brief ISIs. For example, the processing time needed by the LI participants to respond correctly to nonverbal stimuli was considerably longer than that required by matched control children (Tallal & Piercy, 1973). None of the participants with LI reached the criterion of 75% correct performance at 150 ms or less, whereas all of the control children reached 75% correct at ISIs of 8 ms or longer (Tallal, Miller, & Fitch, 1993). Interestingly, the performance of the LI participants was bimodal so that, at slower presentation rates, the LI participants performed as well as the control children in identification, discrimination, and sequencing of the acoustic stimuli, whereas their performance dropped to chance levels when the presentation rate was increased by decreasing the ISI. The authors reported a similar pattern using synthesized consonants and vowels. For the 250-ms two-vowel stimulus pattern, the participants with LI performed as well as the control children at any ISI studied. However, for the consonant-consonant discrimination, the difference between the participants with LI and the control children was statistically significant for every task (Tallal & Piercy, 1974). For consonant-vowel sequences, the LI participants were impaired when the discriminable elements of the stimuli were brief (43 ms), but unimpaired when these components were longer (95 ms) (Tallal & Piercy, 1975). The authors concluded that the duration of the consonant transitions was the key to the performance of the participants with LI.

As a result of this progression of experiments, Tallal and Piercy advanced the notion that children with language impairments are incapable of perceiving auditory information at a normal rate, and that this constraint on speed of auditory processing may underlie language impairment. Tallal and colleagues suggested that the participants with LI had difficulty in these experiments because of a deficit in processing acoustic signals entering the nervous system in rapid succession (Tallal, Miller, & Fitch, 1993). These latter studies laid the foundation for the premise that children with LLI have poor auditory processing skills. One of the underlying hypotheses of FFW is that this processing deficit is at the core of the language disorder itself. Thus, remediating the processing deficit should greatly reduce or ameliorate the language disorder.

Underlying Hypotheses

Merzenich and Tallal, the creators of FFW, propose that many children with LLI have difficulty recognizing and sequencing rapidly presented visual and auditory information (Merzenich, Jenkins, et al., 1996; Tallal, 1990). They refer to this condition as a temporal processing deficit. Recent research suggests that deficits of this sort may emerge as early as the first year of life (Benasich & Tallal, 1996). Benasich and Tallal (1996) propose that temporal processing deficits may be a biological marker of language impairment.

The temporal processing deficit hypothesis of Merzenich and Tallal posits a general deficit in the processing of acoustic signals entering the nervous system in rapid succession (Tallal et al., 1993). In a series of studies, Tallal and colleagues have reported that children with SLI can be characterized by deficits in aspects of auditory processing, specifically rapid temporal integration of acoustically varying signals (Tallal, 1980, 1981; Tallal & Piercy, 1973, 1974, 1975; Tallal et al., 1997). Tallal has further suggested that a general temporal processing impairment observed in children with LI underlies an inability to integrate sensory information in multiple sensory modalities (Tallal et al., 1993). Because Tallal has reported these deficits for both speech and nonspeech stimuli, she has advanced the notion that the underlying deficit is auditory and therefore generalized rather than specifically limited to speech perception.

Several researchers have challenged the theory of temporal processing deficits (e.g., Bishop, Bishop, et al., 1999; Bishop, Carlyon, Deeks, & Bishop, 1999; Brady, 1997; Nittrouer, 1999). A central issue in this debate is whether LI results from a specific deficit in speech perception (i.e., whether it is speech-specific) or from a more generalized deficit in temporal processing (Friel-Patti, 1999). The speech-specific hypothesis proposes that the processing deficit leading to language impairment is phonetic, not auditory, in origin. Researchers from Haskins Laboratories hold this theoretical position, and it is based on a series of experiments done with children identified with reading disabilities (Liberman, 1973; Mody, Studdert-Kennedy, & Brady, 1997; Studdert-Kennedy, 1997; Studdert-Kennedy & Mody, 1995, Nittrouer, 1999). The fundamental assertion is that the processing deficits are specific to speech and that they arise from difficulty in "identifying the phonological categories of phonetically similar speech sounds rather than from deficits either in temporal order judgment itself or in processing the brief acoustic changes of formant transitions" (Mody et al., 1997, p. 20). This latter hypothesis has yet to be tested in a study of children with LI. Although children with LI are at risk for reading impairments, it is not possible without additional research to extend the results of studies with poor readers to children with LI.

What is Fast ForWord?

FFW is commercially available, on a fee per child basis, via the Internet using CD-ROM software. The program is offered through certified providers who receive specialized training in the theory, research, and technical aspects of the program. FFW has seven computer exercises: three sound exercises (Circus Sequence, Old MacDonald's Flying Farm, and Phoneme Identification) and four word exercises (Phonic Words, Phonic Match, Block Commander, and Language Comprehension Builder). The sound exercises are composed of complex auditory information in a pre-word format using different frequencies, time durations, and phonemes. The word exercises are built around words presented either in isolation or within grammatically complex sentences. The words and sentences used in these exercises have been modified to expand and enhance the rapidly changing acoustic components of normal speech.

An algorithm that prolongs segments and differentially amplifies particular frequencies modifies the speech and nonspeech stimuli in all computer exercises (Nagarajan et al., 1998). The acoustic modifications are gradually decreased as children improve on each task within each exercise. As the child's performance improves, the degree of speech modification decreases. At the highest level of each exercise, the child hears natural, unmodified speech. Children receive trial-by-trial feedback for correct and incorrect responses. When children respond incorrectly, the correct answer is provided prior to the next stimulus. Incorrect responses are also signaled by an auditory cue that differs from the one following a correct response. Points, short songs, and extra animations reward correct responses.

Five of the seven exercises are presented each day for 20-minute periods (a total of 1 hour and 40 minutes per day) until the child reaches a criterion of 90% completion on any five. Percent completion indicates the percentage of the computer exercise the children have mastered or how far they have advanced through the adaptive training levels. Scientific Learning Corporation (the producer of FFW) reports that children often complete the treatment in 30 intervention days, although the outcomes of treatment, as measured by formal language tests, can be predicted reliably after 20 days of treatment (Miller, Linn, Tallal, Merzenich, & Jenkins, in press). The following is brief description of each of the seven exercises excerpted from the technical and training manuals for FFW (SLC, 1999) as well as some recent published descriptions of these exercises.

Sound Exercises

Circus Sequence (CS). Circus Sequence is designed to train a child to process nonverbal sounds more quickly and accurately. The exercise requires the child to identify and reproduce a two-sound sequence of rapidly successive pairs of frequency glides by clicking on two buttons, each corresponding to a specific sound. Children discriminate and sequence two brief successive FM sweeps presented at three base frequencies (.5, 1, or 2 kHz), six stimulus durations (from 80 to 25 ms), and 45 ISIs (from 500 to 0 ms). The frequency sweep rate is constant at 16 dB/octave. Children must remember the sequence of two brief tones that sweep either up or down in frequency. They begin with the longest sweep durations and ISIs and progress gradually to the shortest sweep durations and ISIs. They receive any one of four frequency glide pairs (up-up, up-down, down-up, down-down) and must duplicate the order of stimulus presentation with the computer mouse. The objective of the exercise is to develop a more normal ability to identify brief, rapidly changing, and rapidly successive acoustic stimuli that fall within the same frequency-processing channels of hearing as well as to generalize these abilities across the frequency range required for speech (Merzenich, Tallal, Peterson, Miller, & Jenkins, 1999; SLC, 1999).

Old MacDonald's Flying Farm (OMDFF). In OMDFF, the child uses the computer mouse to "capture" and hold a flying animal. Children must distinguish changes in the initial phonemes in CV syllables. While holding the mouse button down, the child hears a rapid succession of isolated phonemes (such as /gi/, /gi/, /ki/). When the child hears /ki/, he or she is to release the flying animal. OMDFF has five phoneme contrasts using both stop consonants and fricatives (/gi/–/ki/, /ʧu/–/ʃu/, /si/–/sti/, /gɛ/–/ke/, /do/–/to/. For each phoneme contrast pair, one syllable is the target and one is the distractor. The distractor syllable differs from the target by an individual phoneme. In OMDFF, the target syllable is presented in natural speech while the initial consonant of the distractor syllable is modified by extending the voice onset time (VOT) for the stops or by expanding the silent period between the fricative and vowel for the fricatives. When the child hears a different phoneme in the succession, he or she releases the captured farm animal. Phoneme changes relate to VOTs and the duration of the fricative-vowel gaps. During training, the duration of the sounds and the pause between sounds gradually decrease; the ISIs between the CVs step from 1,000 to 300 ms. To reach the highest level, the child must be able to distinguish between phonemes at rates of acoustic change found in normal speech.

Phoneme Identification (PI). Phoneme Identification trains the child to distinguish single phonemes. The child hears a target CV or VCV syllable. Two characters in the game vocalize the two contrasting stimuli in random sequence, and the child's task is to identify the character that produced the target sound. PI features five phoneme contrast pairs that differ by one phoneme (/va/–/fa/, /aba/–/ada/, /ba/–/da/, /be/–/de/, /bi/–/di/). These five phoneme contrasts are presented in 26 levels that differ according to ISI, which varies from 500 to 10 ms. In PI, unlike OMDFF, the consonants of both the target and distractor syllables are modified by expanding the formant transition and increasing amplitude at particular points in the transition. These particular contrasts were selected because they are subject to relatively strong successive signal interference effects in children with SLI and because they cover a broad spectro-temporal range (Merzenich, Tallal, et al., 1999; SLC, 1999).

Word Exercises

Phonic Words (PW). In a classic word discrimination paradigm, PW challenges the child to distinguish between minimal pair words that differ only by an initial consonant (such as bat and pat) or a final consonant (such as pat and pack). The game is intended to provide the child with practice making correct phonetic distinctions between sounds presented in word contexts. As the child progresses through four levels of modified speech and reaches higher levels of proficiency, the speech becomes less and less modified, gradually moving to natural speech. PW has 92 word pairs differing in the initial (onset) or final (offset) sound (Merzenich, Tallal, et al., 1999; SLC, 1999).

Phonic Match (PM). The purpose of this exercise is to provide generalization training for varied conditions in which fine spectrotemporal distinctions are required. Using a standard "concentration" model, PM is a grid of 2 × 2, 3 × 3, or 4 × 4 animated tiles. When the child selects a tile, he or she hears a single word (either CV or CVC syllables) that corresponds to that tile. The child must find the other tile in the grid that evokes the same word. When the child selects the two tiles with matching sounds in successive order, the two tiles disappear. The child is given a limited number of matching attempts on each board, and extra points are awarded if he or she clears the board with fewer match attempts. The number of tiles in the next grid increases if the child clears the previous grid quickly, adding an auditory memory component to the game. The speech stimuli in this exercise are modified by prolonging the speech in time and by amplifying rapidly changing and brief acoustic elements. Nagarajan et al. (1998) described the algorithm used to generate these stimuli in detail. Words within a grid vary in initial (bat–pat) or final (pat–pack) consonants, and they all contain the same vowel sound. The game moves through a large number of word sets. Although PM is classified as a word exercise, it features both sounds (e.g., /ʧa/, /ra/, /la/) and words. PM has 48 sounds and words that vary in either initial or final consonants. The child works through all the speech levels until reaching unprocessed (normal) speech (Merzenich, Tallal, et al., 1999; SLC, 1999).

Block Commander (BC). Block Commander is a three-dimensional board game filled with familiar colored shapes that the child selects and manipulates. This game is related to the progressively challenging commands of the Token Test for Children (DiSimoni, 1978). The game focuses on increasing a child's listening comprehension and attention skills by asking him or her to follow increasingly complex commands. The child receives instructions to point to or move different colored geometric shapes on the game board depicted on the computer monitor. He or she moves the shapes in two-dimensional space using the computer mouse. BC has 58 commands of increasing cognitive difficulty that range from simple, one-step instruction to multi-step commands that require understanding of prepositional phrases. Progressively higher levels of difficulty within the game are reflected in longer sentences and increased syntactic difficulty. Across training sessions the amount of speech processing is systematically decreased to provide a challenging interactive board game, using natural speech at the highest level.

Language Comprehension Builder (LCB). The objective of LCB is to train a child to make appropriate grammatical distinctions in a sentence context. This exercise is adapted from the Curtiss and Yamada Comprehensive Language Evaluation–Receptive (CYCLE–R) assessment battery developed by Curtiss and Yamada (1985, unpublished). LCB presents children with pictures depicting actions and complex relational themes to build their phonological, morphological, and grammatical comprehension skills. Children must match the spoken sentences with the correct picture. Using 200 sentences that describe actions and complicated relational themes, LCB trains participants on 38 specific areas of language comprehension including increasingly complex phonological, syntactic, and morphological structures. Once again, the child progresses through five levels of speech modifications until reaching normal (unmodified) speech (Merzenich, Tallal, et al., 1999; SLC, 1999).

Studies of FFW

Two widely disseminated pilot studies served as the foundation for the development of FFW. Both involved a relatively small sample of children (Merzenich, Jenkins, et al., 1996; Tallal et al., 1996), The developers of FFW have also conducted a large field trial, whose results have been reported at professional meetings (Tallal et al., 1997), but have not been summarized in a peer-reviewed journal at the time of this writing.

In the first study, seven 5- to 9-year-old children with SLI received language intervention 3 hours per day, 5 days per week, for 4 weeks. The children were characterized as having normal nonverbal intellectual abilities, delays in receptive and expressive language development, and reading difficulties. They played prototypes of two FFW exercises (Circus Sequence and Phoneme Identification), and they also rotated through eight other speech and language exercises that were presented by trained clinicians in individual sessions with the participants. In addition, children completed 1 to 2 hours of homework every day that involved listening to stories.

These interventions all involved multiple repetitions, small increments in difficulty level, and rewards for effort and success (Merzenich, Jenkins, et al., 1996). The speech stimuli in the activities were modified by prolonging formant transitions while amplifying certain phonetic elements so that they would be more easily discriminated by children with temporal processing problems. A process that prolonged the formant transitions in consonants and, at the same time, amplified certain phonetic elements accomplished this. The speech modifications were gradually reduced as the children's performance on the intervention tasks improved.

The children's performance on the Circus Sequence and the Phoneme Identification exercises improved significantly during the 4-week period (Merzenich, Jenkins, et al., 1996); performance on the other eight language intervention exercises was not reported. The children also improved significantly on the Tallal repetition test (an auditory perception task that requires children to recognize and sequence tones that are presented with progressively shorter durations and ISIs and on formal tests of memory for commands and grammatical comprehension, i.e., The Token test, the CYCLE–R, and the Test of Language Development—Primary (TOLD; Newcomer & Hammill, 1997) (Tallal et al., 1996). Improvement on the Tallal Repetition Test was highly correlated with posttraining performance on the Token Test, suggesting that changes in temporal processing were related to changes in processing language.

A second study (Merzenich, Jenkins, et al., 1996; Tallal et al., 1996) was conducted with 22 children with SLI who ranged in age from 5;4 to 10;0 years. These children were divided into two matched groups according to nonverbal intelligence and receptive language abilities. Children in both groups attended laboratory sessions for 3.5 hours each day. The children in the second group also completed 1 to 2 hours of listening homework per day.

The groups differed according to the auditory stimuli that were presented. Children in one group listened to modified speech as they played revised versions of the Circus Sequence and Phoneme Identification exercises that were used in Experiment 1 and two additional exercises, Old MacDonald's Flying Farm and Phonic Match, that are part of the current FFW package. They also listened to modified speech in the clinician-directed intervention sessions each day and in their daily homework sessions. The children in the second group, "received equivalent language training but with natural speech materials," and they "played video games rather than these adaptive auditory-speech training games" (Merzenich, Jenkins, et al., 1996, p. 80).

After training, children in both treatment groups improved significantly on all measures. The children whose language intervention included modified speech stimuli evidenced greater improvement on measures of temporal processing, speech discrimination, and grammatical comprehension than children in the natural speech treatment group. Again, improvement on the Tallal repetition test, a measure of temporal processing, was highly correlated with posttraining performance on the Token Test for Children (DiSimoni, 1978), which is a measure of language processing.

The results of the studies by Merzenich, Jenkins, et al. (1996) and Tallal et al. (1996) suggested that intensive treatment (4 to 5 hours per day) including computerized auditory perception exercises, clinician-client intervention, and daily homework resulted in significant improvements on tests of auditory perception, memory, and language comprehension. These improvements were enhanced when children were exposed to modified speech stimuli during treatment. These results are quite dramatic and promising, but clinicians should be aware that they do not demonstrate the efficacy of the current FFW program. Since the 1996 studies, the original pilot intervention program has been expanded to include two new exercises, namely, Language Comprehension Builder and Block Commander. Seven exercises now comprise FFW.

Recently, Merzenich, Tallal, and their colleagues conducted a large field study of the currently available FFW program (Tallal et al., 1997). In this study, 500 children received FFW training from 58 professionals who had attended a certification seminar. Participants varied in degree of SLI (mild to severe), their diagnosis (SLI, autism, pervasive developmental disorder, central auditory processing disorder, attention deficit disorder, dyslexia, or no diagnosed disorder), and the amount of training that they received (from 4 to 6 weeks). The test batteries used to measure language change varied across the test sites. Across disorder types and ability levels, most of the children gained approximately 1 standard deviation on most of the measures. Although these gains appear to be large, it is important to consider the difficulties inherent in interpreting the results of different measures administered to children with different diagnoses, different ability levels, and different amounts of treatment. Other flaws in the design and methods of this study include inadequate subject selection criteria, limited control of assessment procedures, lack of control of Rosenthal effects, and failure to include a no-treatment or a delayed treatment control group. It is also unfortunate that the investigators did not collect pre- and posttraining samples of spontaneous language.

To date, the published research assessing the efficacy of FFW promotes an intervention approach full of promise. However, a closer look at the limitations of these studies within a clinical outcome research model would suggest that the work on FFW is preliminary and requires further scrutiny of its effectiveness.

Clinical Outcome Research

Robey and Schultz (1998) propose a five-step model for conducting clinical outcome research based on a health care outcome model. The clinical outcome model has five phases. The first two phases are especially pertinent for setting the stage for future large-scale research with control groups and have much in common with the articles in this issue on FFW. Phase I studies are conducted by means of small group experiments, single-subject experiments, and case studies. The Phase I study is explorative in that it asks many questions regarding the usefulness of the intervention, ranging from what measures change to how a change affects a person's daily life. Phase I studies also document that no harm has occurred as a result of the intervention. The safety of an intervention must be determined before the next phase is attempted. According to Robey & Schultz (1998), Phase I studies characteristically lack external control and have small numbers of participants. Information gained in these studies define and form the larger, controlled studies that follow. It is important to note that the goal of Phase I studies is not to establish efficacy; but rather to determine whether the intervention shows promise, and if so, to define the boundaries of that promise in a limited sample.

Phase II studies, like Phase I studies, are critical for developing hypotheses and evaluating the outcome of a given intervention. They are not efficacy studies, but they are critical to accomplishing future efficacy research. Phase II studies also include single-subject design and case studies. They provide information about participants for whom the intervention may be useful, as well as specifics such as appropriate length of intervention and type of reinforcement. Tools for measuring change are evaluated for their usefulness as target variables are examined. In addition, during Phase II studies, the researcher examines the durability of any changes made by participants. Documenting that positive changes are maintained is a crucial step before continuing with Phase III studies.

Phase III studies test the hypotheses of Phase I and II studies under the best possible conditions. Phase III studies have large experimental and control groups and often different intervention conditions. These studies ideally take place across multiple sites. In contrast to Phase III studies, which focus on efficacy, Phase IV studies evaluate the effectiveness of an intervention. The effectiveness is evaluated under typical, clinical circumstances. Phase IV studies use large groups of participants; however, in some cases, carefully controlled single-subject designs may be used. The types of participants included may also be manipulated to understand the intervention's effect on different populations. Alternatively, certain aspects of the intervention may be manipulated to determine if the effectiveness of the intervention is altered. Phase V studies also involve large number of participants, but they do not have external control participants. These studies often focus on the cost effectiveness and consumer satisfaction with the intervention.

The pioneering research on FFW (Merzenich, Jenkins, et al., 1996; Tallal et al., 1996) can be classified as Phase I and Phase II type studies. Phase II studies involved small populations and explored hypotheses related to the usefulness of the intervention. In contrast, the large-scale field study (Tallal, 2000) was similar to a Phase V effectiveness study because it lacked control participants and was performed in clinical situations. However, its goal was not at a Phase V level (e.g., to establish cost-effectiveness and consumer satisfaction). Instead, its goal was more consistent with that of a Phase III study, yet it lacked the sufficient control participants and safeguards specified in Robey and Schultz's model (1998). From our perspective, the large-scale field trial was premature, since the Phase III efficacy study had not been completed with adequate numbers and control participants.

In this issue, Friel-Patti, DesBarres, and Thibodeau (2001), Gillam, Crofford, Gale, and Hoffman (2001), and Frome Loeb, Stoke, and Fey (2001) provide studies that meet the criteria of Phase I and Phase II studies. They are Phase I studies because of their small numbers of participants and their limited control participants. Further, they are aimed at exploring which areas of language may change as a result of FFW, as well as evaluating different measurement tools for obtaining these data. They are Phase II studies because they carefully analyze the changes in a wide range of variables, and some (Frome Loeb et al., 2001) evaluate the long-term effects of the intervention. Although these latter studies cannot address the efficacy of FFW, in terms of clinical outcome research, they provide critical information for future Phase III, IV, and V efficacy and effectiveness studies.

The studies in this issue not only provide guidance for future efficacy research, but they also provide clinicians with much needed detailed information on how FFW works with children with LLI. Fey and Johnson (1998) point out that researchers and clinicians are interested in fundamentally different questions and need to answer these questions using different methods. These questions might include, but are not limited to, determining which children are successful with the program, in what areas gains are observed beyond standardized testing, and to what extent are parents and children satisfied with the intervention. Clinicians may also want to know if changes are maintained over time. Case studies and single-subject design studies can provide a detailed analysis of the program's generalization to everyday language. Fey and Johnson (1998) propose that only through a combination of large group experimental studies and smaller case studies can both researchers and clinicians be convinced of the clinical significance of a given intervention.

Conclusion

Every new intervention procedure that is developed should be rigorously questioned and tested in an effort to understand the theoretical model of the intervention and the nature of the changes that ensue within the child with LI. In this clinical research forum, we provide a series of articles that contain case studies and within-subject experimental design studies conducted in independent research laboratories. Our goal is to evaluate the effectiveness of FFW intervention on individual children so that we can provide a detailed picture of intervention progress and gains in areas not previously documented. The articles that follow provide important information about the changes that occur after FFW intervention as well as the possible relationship of these changes to improved temporal processing skills. Together, this series of investigations offers a multi-site, multi-faceted examination of the computer-based intervention program Fast ForWord.

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References

Aram, D. M., & Hall, N. E. (1989). Longitudinal follow-up of children with preschool communication disorders: Treatment implications. *School Psychology Review, 18*(4), 487–501.

Aram, D. M., & Nation, J. E. (1980). Preschool language disorders and subsequent language and academic difficulties. *Journal of Communication Disorders, 13*, 159–170.

Benasich, A. A., & Tallal, P. (1996). Auditory temporal processing thresholds, habituation, and recognition memory over the 1st year. *Infant Behavior & Development, 19*(3), 339–357.

Bishop, D. V. M., & Adams, C. (1990). A prospective study of the relationship between specific language impairment, phonological disorders and reading retardation. *Journal of Child Psychology and Psychiatry, 31*, 1027–1050.

Bishop, D. V. M., Bishop, S., Bright, P., James, C., Delaney, T., & Tallal, P. (1999). Different origin of auditory and phonological processing problems in children with language impairment: Evidence from a twin study. *Journal of Speech, Language, Hearing Research, 42*(1), 155–168.

Bishop, D. V. M., Carlyon, R. P., Deeks, J. M., & Bishop, S. J. (1999). Auditory temporal processing impairment: Neither necessary nor sufficient for causing language impairment in children. *Journal of Speech, Language, and Hearing Research, 42*, 1295–1310.

Bishop, D. V. M., & Edmundson, A. (1987). Specific language impairment as a maturational lag: Evidence from longitudinal data on language and motor development. *Developmental Medicine & Child Neurology, 29*(4), 442–459.

Brady, S. A. (1997). Ability to encode phonological representations: An underlying difficulty of poor readers. In B. A. Blachman (Ed.), *Foundations of reading acquisition and dyslexia: Implications for early intervention* (pp. 21–47). Mahwah, NJ: Lawrence Erlbaum.

Curtiss, S., & Yamada, J. (1985). Curtiss-Yamada Comprehensive Language Evaluation–Receptive. Unpublished lab version.

DiSimoni, F. (1978). *Token Test for Children*. San Antonio, TX: Psychological Corporation.

Efron, R. (1963). Temporal perception, aphasia and deja vu. *Brain, 86*, 403–424.

Fey, M. E., & Johnson, B. W. (1998). Research to practice (and back again) in speech-language intervention. *Topics in Language Disorders, 18*(2), 23–34.

Friel-Patti, S. (1999). Clinical decision-making in assessment and intervention of central auditory processing disorders. *Language, Speech, and Hearing Services in Schools, 30*(4), 345–352.

Friel-Patti, S., Desbarres, K., & Thibodeau, L. (2001). Case studies of children using Fast ForWord. *American Journal of Speech-Language Pathology, 10*, 203–215.

Frome Loeb, D., Stoke, C., & Fey, M. E. (2001). Language changes associated with Fast ForWord-Language: Evidence from case studies. *American Journal of Speech-Language Pathology, 10*, 216–230.

Gillam, R. B. (1999). Computer-assisted language intervention using Fast ForWord. *Language, Speech, and Hearing Services in Schools, 30*(4), 363–370.

Gillam, R. B., Crofford, J. A., Gale, M. A., & Hoffman, L. M. (2001). Language change following computer-assisted language instruction with Fast ForWord or Laureate Learning Systems software. *American Journal of Speech-Language Pathology, 10*, 231–247.

Hardy, J. (1965). On language disorders in young children: A reorganization of thinking. *Journal of Speech and Hearing Disorders, 30*, 3–16.

Leonard, L. B. (1998). *Children with specific language impairment*. Cambridge, MA: MIT Press/Bradford Book.

Liberman, I. Y. (1973). Segmentation of the spoken word. *Bulletin of the Orton Society, 23*, 65–77.

Lowe, A., & Campbell, R. N. (1965). Temporal discrimination in aphasoid and normal children. *Journal of Speech and Hearing Research, 8*, 313–314.

Merzenich, M. M., Jenkins, W. M., Johnston, P., Schreiner, C., Miller, S. L., & Tallal, P. (1996). Temporal processing deficits of language-learning impaired children ameliorated by training. *Science, 271*, 77–81.

Merzenich, M. M., Saunders, G., Jenkins, W. M., Miller, S., Peterson, B., & Tallal, P. (1999). Pervasive developmental disorders: Listening training and language abilities. In S. H. Broman & J. M. Fletcher (Eds.), *The changing nervous system: Neurobehavioral consequences of early brain disorders* (pp. 365–385). New York: Oxford University Press.

Merzenich, M. M., Tallal, P., Peterson, B., Miller, S., & Jenkins, W. M. (1999). Some neurological principles relevant to the origins of—and the cortical plasticity based remediation of—developmental language impairments. In J. Grafman & T. Christen (Eds.), *Neuronal plasticity: Building a bridge from the laboratory to the clinic* (pp. 169–187). New York: Springer-Verlag.

Merzenich, M., Wright, B., Jenkins, W., Xerri, C., Byl, N., Miller, S., & Tallal, P. (1996). Cortical plasticity underlying perceptual, motor, and cognitive skills development: Implications for neurorehabilitation. *Cold Spring Harbor Symposia on Quantitative Biology, 61*, 1–8.

Miller, S. L., Linn, N., Tallal, P., Merzenich, M. M., & Jenkins, W. M. (in press). Acoustically modified speech and language training: A relationship between auditory word discrimination training and measures of language outcome. *Reeducation Orthophonique*.

Mody, M., Studdert-Kennedy, M., & Brady, S. (1997). Speech perception deficits in poor readers: Auditory processing or phonological coding? *Journal of Experimental Child Psychology, 64*, 199–231.

Nagarajan, S. S., Wang, X., Merzenich, M. M., Schreiner, C. E., Johnston, P., Jenkins, W. M., Miller, S., & Tallal, P. (1998). Speech modifications algorithms used for training language learning-impaired children. *IEEE Transactions on Rehabilitation Engineering, 6*(3), 257–268.

Newcomer, P. L., & Hammill, D. D. (1997). *Test of Language Development: Primary–3* (3rd ed.). Austin: Pro-Ed.

Nittrouer, S. (1999). Do temporal processing deficits cause phonological processing problems? *Journal of Speech, Language, and Hearing Research, 42*(4), 925–942.

Robey, R. R., & Schultz, M. C. (1998). A model for conducting clinical-outcome research: An adaptation of the standard protocol for use in aphasiology. *Aphasiology, 12*(9), 787–810.

Scientific Learning Corporation. (1997). *Fast ForWord™* (version 1.5). Berkeley, CA: Author.

Scientific Learning Corporation. (1999). *Fast ForWord Companion: A comprehensive guide to the training exercises, version 1.5*. Berkeley, CA: Scientific Learning Corporation.

Scientific Learning Corporation Web Site. (2001, January). http://www.scilearn.com.

Snowling, M., & Hulme, C. (1989). A longitudinal case study of developmental phonological dyslexia. *Cognitive Neuropsychology, 6,* 379–401.

Stothard, S. E., Snowling, M. J., Bishop, D. V. M., Chipchase, B. B., & Kaplan, C. A. (1998). Language-impaired preschoolers: A follow-up into adolescence. *Journal of Speech, Language, Hearing Research, 41*, 407–418.

Studdert-Kennedy, M. (1997). *Deficits in phoneme awareness do not arise from failures in rapid auditory temporal processing.* Paper presented at the Meeting on Basic Neural Mechanisms in Cognition and Language with Special Reference to Phonological Problems in Dyslexia, Stockholm, Sweden.

Studdert-Kennedy, M., & Mody, M. (1995). Auditory temporal perception deficits in the reading-impaired: A critical review of the evidence. *Psychonomic Bulletin and Review, 2*(4), 508–514.

Tallal, P. (1980). Language disabilities in children: A perceptual or linguistic deficit? *Journal of Pediatric Psychology, 5*(2), 127–140.

Tallal, P. (1981). Language disabilities in children: Perceptual correlates. *International Journal of Pediatric Otorhinolaryngology, 3,* 1–13.

Tallal, P. (1990). Fine-grained discrimination deficits in language-learning impaired children are specific neither to the auditory modality nor to speech perception. *Journal of Speech and Hearing Research, 33*(3), 616–617.

Tallal, P. (2000). Experimental studies of language learning impairments: From research to remediation. In D. V. M. Bishop & L. B. Leonard (Eds.), *Speech and language impairments in children: Causes, characteristics, intervention and outcomes* (pp. 131–155). Philadelphia: Psychology Press.

Tallal, P., Merzenich, M., Burns, M., Gelfond, S., Young, M., Shipley, J., & Polow, N. (1997). *Temporal training for language-impaired children: National clinical trial results.* Paper presented at the American Speech-Language-Hearing Association Annual Convention, Boston, MA.

Tallal, P., Miller, S. L., Bedl, G., Byma, G., Wang, X., Nagarajan, S. S., Schreiner, C., Jenkins, W. M., & Merzenich, M. M. (1996). Language comprehension in language-learning impaired children improved with acoustically modified speech. *Science, 271,* 81–84.

Tallal, P., Miller, S., & Fitch, R. H. (1993). Neurobiological basis of speech: A case for the preeminence of temporal processing. *Annals of the NY Academy of Sciences, 682,* 27–47.

Tallal, P., & Piercy, M. (1973). Developmental aphasia: Impaired rate of nonverbal processing as a function of sensory modality. *Neuropsychologia, 11*(4), 389–398.

Tallal, P., & Piercy, M. (1974). Developmental aphasia: Rate of auditory processing and selective impairment of consonant perception. *Neuropsychologia, 12*(1), 83–93.

Tallal, P., & Piercy, M. (1975). Developmental aphasia: The perception of brief vowels and extended stop consonants. *Neuropsychologia, 13,* 69–74.

Tomblin, J. B., Records, N. L., & Zhang, X. (1996). A system for the diagnosis of specific language impairment in kindergarten children. *Journal of Speech and Hearing Research, 39*(6), 1284–1294.

U.S. Department of Education. (1997). To assure the free appropriate public education of all Americans: *Nineteenth annual report to Congress on the implementation of the Individuals with Disabilities Education Act.* (Publication No. 1997-616-188/90444). Washington, DC: U.S. Government Printing Office.

Veale, T. K. (1999). Targeting temporal processing deficits through Fast ForWord. *Language, Speech, and Hearing Services in the Schools, 30*(4), 353–362.

Wright, B. A., Lombardino, L. J., King, W. M., Puranik, C. S., Leonard, C. M., & Merzenich, M. M. (1997). Deficits in auditory temporal and spectral resolution in language-impaired children. *Nature, 387,* 176–178.

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